BIOLOGICAL EVALUATION OF JACK-PINE BUDWORM FOR CHEQUAMEGON, CHIPPEWA, HIAWATHA, HURON, MANISTEE, NICOLET, OTTAWA, AND SUPERIOR NATIONAL FORESTS--1967

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I. INTRODUCTION

The jack-pine budworm, Choristoneura pinus Freeman, is one of the most serious pests of jack pine in the Lake States. Scotch and red pines are also attacked when mixed with or near jack pines.

The most common economic losses are from tree mortality, top kill, growth loss, seed loss, and reproduction loss.

Many parasites are known to attack all stages of budworm; however, their role in population regulation is not clear.

Silvicultural conditions appear related to budworm outbreaks and eventual losses from defoliation. Conditions favoring staminate flower production also favor successful budworm development in the spring.

Poor vigor trees, such as mature, diseased, or stagnating pines, are more likely to succumb from budworm defoliation. Trees on poor and medium sites appear more vulnerable to budworm damage.

Aerial defoliation surveys on over more than 12 million acres revealed several extensive budworm outbreak areas. Severe budworm defoliation occurred on the Chequamegon, Chippewa, Hiawatha, and Ottawa National Forests.

Population trend surveys, utilizing permanent plot sample points and measuring egg masses or pupal populations, were conducted on eight National Forests. Continued high budworm populations, or possible increases, are predicted for the Chequamegon, Hiawatha, and probably Ottawa National Forests.

Silvicultural control measures are suggested that should reduce future budworm problems.

Three insecticides used for jack-pine budworm control are evaluated. On the basis of effectiveness for larval kill, DDT is recommended at 1 lb. tech. per gallon of No. 2 fuel oil per acre. Malathion is given as an alternate choice, although it has been less effective than DDT. Malathion needs a large-scale field application to determine its effectiveness under operational conditions. Zectran is an effective budworm insecticide, but is not available commercially.

The biological recommendations are as follows:

1. Re-examination of timber management practives to incorporate silvicultural control suggestions for jack-pine budworm in all Forests.

2. Chemical suppression is recommended for Chequamegon and Hiawatha National Forests if resource values justify it. DDT is recommended, and Malathion is suggested as a second choice.

3. Chippewa and Ottawa National Forests are advised that additional evaluation is needed to determine if chemical suppression is advisable.

II. TECHNICAL INFORMATION

A. Causal Agent

Choristoneura pinus Freeman, jack-pine budworm.

B. Host Trees Attacked

Pinus banksiana Lambert, jack pine.
Pinus resinosa Aitken, red pine.
Pinus sylvestris L., Scotch pine.
Various other conifers are fed on when present in high budworm population areas, but the damage is not considered economically important.

C. Type of Damage

The jack-pine budworm is primarily a defoliator. In addition, feeding injury may occur on staminate flowers, buds, and tender bark of young twigs. Thus, the damage to the tree depends on the type and the intensity of the injury. The following types of tree damage are discussed in detail because of the economical implications for the timber manager.

1. Tree kill
2. Tree top kill
3. Growth loss
4. Mortality of young reproduction
5. Seed loss

Tree Kill

The most severe budworm damage results in pine mortality. Weather, site, and vigor of the tree greatly contribute toward the tree's chances of survival. In general, the following type of budworm injury to the tree will result in its death:

1. Defoliation in excess of 80 percent of total foliage for red pine; a somewhat greater percent for jack pine.

2. Extensively damaged buds and twigs that prevent effective refoliation the following spring.

Jack pine growing on sandy soils, particularly during dry years, is more susceptible to mortality than vigorous trees on good sites.

Similarly, older trees are more likely to die than younger ones. Small-crowned trees, such as found at high stand density, are killed quicker than large-crowned trees. In addition, due to the initial effect of the budworm, secondary pests, such as bark beetles, and diseases may kill trees that otherwise might survive.

In the past, jack-pine budworm caused tree mortality has been variable. Shenefelt and Benjamin (1955) state that the budworm has killed thousands of cords of marketable jack pine. Benjamin et al. (1961) state that mass kill of large areas is not common. They report that in Wisconsin tree mortality is highest among suppressed and intermediate trees, with kill over 50 percent of stems reported. Kulman et al.(1963) report tree mortality in Minnesota between 29-40 percent after severe defoliation. In Lower Michigan, 9-28 percent commercial volume loss was recorded after 1963-66 budworm eruption (Millers 1966). The stands measured were selected from previous defoliation maps and all had been severely defoliated at least once.

The obvious conclusion from these reports is that jack-pine budworm can cause tree mortality, but the severity can vary.

Tree Top Kill

Severe defoliation to the upper part of tree crowns results in top kill. The extent of top kill may vary from a dead bud or shoot to more than three-fourths of the tree trunk. The economic loss occurs from volume and quality loss. Top kill is the most common type of damage associated with jack-pine budworm defoliation (Graham 1935; Kulman et al. 1963). Loss of the upper few feet of a jack pine top does not represent economic loss. However, the flat-topping may contribute toward increased staminate flower production, and therefore create a more favorable environment for future budworm outbreaks (Kulman et al. 1963). On red pine under 18 feet in height, top kill results in an eventual crook or fork that is considered a serious defect for high-quality lumber or utility poles. Top kill on red pine is common when the trees are mixed with jack pine or adjoin older jack pine stands.

Severe defoliation often results in mortality of tops that include one or more pulpwood sticks. This is more common on large-crowned trees. The loss of the commercial volume in tree tops may be significant. In addition, due to the loss of part of the tree, the whole tree may become unmerchantable because of reduced volume. Also, wood rots may develop in the top and proceed downward, thus reducing commercial volume.

Growth Loss

Jack pine mortality and top kill is obvious and is first to attract the attention of the forest manager. However, more common and greater losses occur from reduced tree growth as a result of budworm defoliation. Only one study is reported that shows the effects of jack-pine budworm defoliation on tree growth; a modified table is reproduced here (Kulman et al. 1963).

Table 1.--Percent reduction in average ring growth area[1/] on jack pine after 1956 defoliation in Minnesota (modified from Kulman et al. 1963)

Defoliation Class	1956	1957		1958	
	Summer wood	Spring wood	Summer wood	Spring wood	Summer wood
	-Percent-				
Light, less than 20 percent	32	54	27	8	0
Medium, 21-60 percent	60	76	44	1	0
Severe, 61-90 percent	83	100[2/]	73	52	20
Very severe, 90+ percent	106[2/]	100[2/]	91	86	86

[1/] Data represents four measurements in each of five positions of the sample tree.

[2/] The percentage of 100 and over are the result of mathematical calculation and should be considered as 99 percent.

Table 1 shows that even light defoliation results in growth loss. More severe defoliation has reduced growth greatly even 3 years after defoliation. While this table represents growth reduction on selected trees by defoliation class, the figures can also be applied to stand conditions. One can only speculate how much of this growth reduction from defoliation is incorporated in the timber managers expected growth yield figure of 0.35 cords/acre/year.

Mortality of Young Reproduction

Frequently, jack pine reproduction is established under older pines. The timber manager expects to have this reproduction after the harvest of the older trees. However, jack-pine budworm defoliation on this reproduction is severe and tree mortality is common. Benjamin et al. (1961) report that 90-100 percent of reproduction may be killed in Wisconsin. Consequently, the manager may be required to plant after tree harvest, and the planting cost would represent economical loss from the budworm.

Seed Loss

The small budworm larvae feed on and damage the staminate flower stems. Some reduction in pollen is suspected, but it is doubtful that extensive current seed reduction occurs because of insufficient pollen. However, staminate flower production is reduced following budworm defoliation (Graham 1935; Heron and Nairn 1963). Kulman et al. (1963) found that staminate flower production is reduced for as long as 3 years after defoliation. Cone production was reduced even in the year of defoliation as a result of direct budworm damage. Reduced seed production by budworm defoliation should be considered when that seed is needed for reproduction after clear cutting or prescribed burning.

In summary, jack-pine budworm defoliation can cause varied effects on its host. Of economical significance to the forest manager is (1) tree mortality, (2) volume and quality loss of top kill, (3) growth loss, (4) mortality of reproduction, and (5) reduced seed and cone production. The extent of losses are related to the intensity of defoliation and the vigor of the trees. Complete tree mortality over large areas is rare, but less obvious damage is more widespread and may be more important in long-range planning.

D. Biological Factors

Life History

A brief summary of the life history of the jack-pine budworm is presented here to provide a basic understanding of the close relationship between the budworm and jack pine.

Adult moths emerge in late June or early July and lay eggs in masses of about 100 per mass on older foliage of jack and red pines. Shortly, the young larvae hatch and without feeding, search out overwintering

sites--loose bark and cone scales. There they spin hibernacula, molt into the second instar, and hibernate. In the spring, young larvae emerge and enter staminate flowers. While larvae may survive without the latter, the mortality rate of the larvae appears high. Only when the initial larval population is high does significant defoliation occur in stands without staminate flowers.

After staminate flowers begin to dry out, the larvae leave and begin to feed on the new foliage. After the new needle supply is exhausted, the larvae attack older needles. Larvae beyond the fourth instar survive well on older foliage. Differences in volume of foliage consumed and feeding preference are reported, but causes are not known. General observations indicate that cool and moist weather decreases feeding.

About mid-June larvae pupate and new adults soon emerge. The progress of budworm development is related to weather. Southern areas of jack pine can expect 2-3 weeks earlier budworm development than in the more northern areas. Similarly, budworm development can vary in the same area due to local climatic variation.

Parasites

A number of insect parasites are reported by various authors, but their impact on budworm population trends is not known (Dixon and Benjamin 1963; Kulman 1961). A brief summary of the more important parasites is presented here.

The primary egg parasite is Trichogramma minutum Reily. While 5-10 percent parasitism is recorded, its effect on population eruption is not known.

The overwintering larvae are attacked by Apanteles fumiferanae Vier. with parasitism about 20 percent reported.

Mature larvae are parasitized by the fly, Lypha setafacies (West).

The prime pupal parasite is Itoplectis conquisitor (Say) that kills 10-30 percent of the pupae.

Virus diseases are suspected of reducing budworm populations, but data are lacking.

Host Influence

One of the most important host conditions related to budworm outbreaks appears to be the availability of staminate flowers (Graham 1935; Lejeune and Black 1947 and 1950). Little is known about annual fluctuations in abundance of staminate flowers. Heron and Nairn (1965) report that in Manitoba, Canada, staminate flowers were present annually, except 1 year, when late frost was suspected of killing them.

Budworm defoliation itself reduces staminate flower production for several years (Kulman et al. 1963). This writer has observed repeatedly that stands severely defoliated do not produce staminate flowers. The lack of staminate flowers reduces the chances of budworm survival during the early spring (Lejeune and Black 1947).

Since the production of staminate flowers appears closely related with budworm survival, it can be said that outbreak conditions are favored by an abundance of staminate flowers. Therefore, the following host conditions may be considered as favoring the development of outbreaks because they tend to increase staminate flower production.

1. Open grown, large crown trees; frequently called orchard- or apple-jack.

2. Old trees of low vigor; usually indicated by flaking bark or cherry-bark.

3. Stagnating or suppressed, low-vigor trees.

4. Trees weakened by galls, wounds, or other damage.

5. Flat-topped trees; usually a sign of old age or as a result of previous top kill.

6. Heavy thinning tends to increase flowering until crown closure.

Epiphytotics

The course of a budworm outbreak or eruption is called an epiphytotic. It usually begins with an explosive increase in budworm numbers, persistance of the high numbers for 2-4 years, and then followed by rapid decline. Occasional 1-year outbreaks are reported. The reasons for the sudden increase or decrease of budworm populations are not known, but studies currently being conducted by Dr. H. O. Batzer, North Central Forest Experiment Station, and Dr. F. B. Knight, University of Michigan should give some insight in the near future.

E. Environmental Factors

Very little is known about the influence of environmental factors on budworm survival. However, wind may play an important role in budworm distribution. Apparently, small budworm larvae and egg-laden females are aided by wind currents to reach distant host pines. These conclusions are drawn from field observations and related information from spruce budworm studies.

F. Location and Extent of Outbreak

The jack-pine budworm in 1967 occurred in outbreak proportions in all three Lake States. The most severe defoliations occurred in northern Wisconsin and Upper Michigan. In Minnesota, budworm defoliation was observed over much of the jack pine range, but only one small area was moderately defoliated on a National Forest.

Aerial detection surveys were made of all the National Forests and some state and private lands. A U.S. Forest Service twin-engine Aero-Commander was used for surveying all of the National Forests except the Superior where DeHaviland Beavers were used. A crew of one navigator and two observers sketch-mapped all significant tree abnormalities visible from the air. Most of the flights followed a grid-iron pattern following township lines or were spaced about 6 miles apart. Most of the flights were at 1,000 feet above ground. The average airspeed was 150-180 miles/hour. The aerial observers followed these guidelines for classifying pine defoliation:

1. None--No visible browning.

2. Light--Browning barely visible; few scattered brown areas within green overall type.

3. Moderate---Browning is obvious, but green foliage also is visible; small areas may be very brown but some pockets are also green.

4. Severe--Much of the area is brown, with only a few scattered spots showing green foliage.

Generally, the observers did not have any problems classifying the defoliation after the first few days of observing. Difficulties were encountered when red pine was mixed with jack pine, and both were attacked by the budworm. Here, defoliation was overestimated. In some areas, severe local storms had knocked down the dead needles and light defoliation was not visible from the air. All major jack pine areas, except for the Baraga Plains on the Ottawa, were ground checked. The ground checks were used to confirm aerial observations. Ocular estimates were made

on defoliation and then related to aerial sketch maps. The defoliation classes reported here are based on the following estimated degrees of defoliation.

None--Budworm feeding absent or very scattered; very few pupal skins on twigs.

Light--Defoliation obvious, but less than 50 percent of current foliage removed (less than 25 percent total defoliation); pupal skins common.

Moderate--Defoliation obvious, with thinning tree crowns; more than 26 percent of foliage removed, but more than 20 percent of old needles remaining on the tree.

Severe--Practically all the needles removed; defoliation more than 81 percent. Some moderately defoliated trees may be present.

Very severe--This classification was reserved for areas where uniform and complete defoliation occurred over areas of more than 10 acres.

Chequamegon National Forest

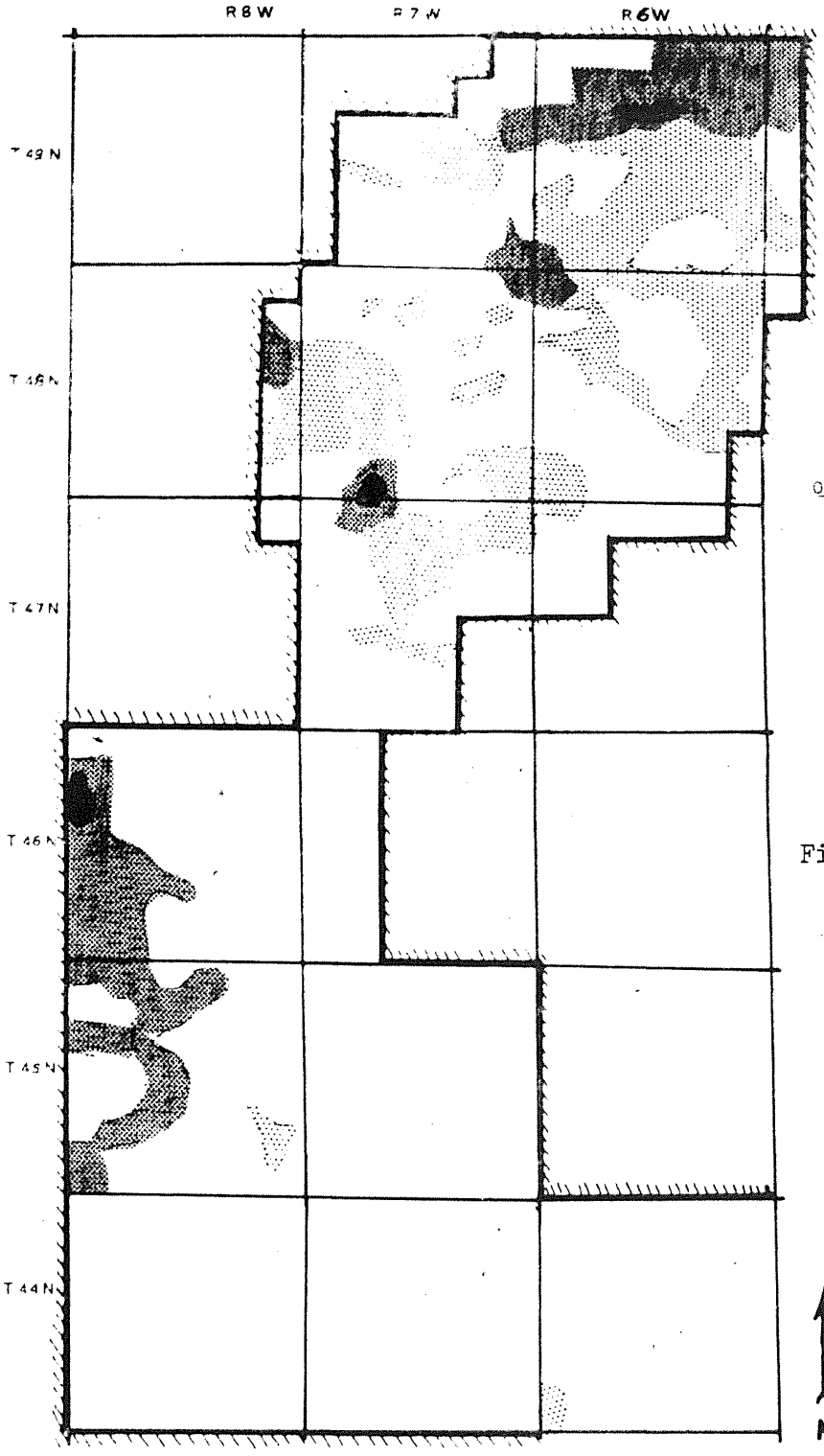
Most of the jack pine type is found on the Washburn Ranger District in the northwest corner of the Forest. This area represents the east edge of an extensive jack pine type in northwestern Wisconsin. The budworm outbreak began in 1965 in the west. On the Washburn Ranger District it erupted in 1966 (Ryan 1966).

In 1967, the budworm defoliation increased in extent and intensity. The defoliation pattern is shown on the map (fig. 1).

About 2,000 gross acres in three small areas received severe defoliation where some tree mortality and top kill is expected. These areas should be re-examined after fall needle drop to evaluate need for salvage. The present estimate is that tree mortality can be expected on 10-20 percent of the commercial volume. Top kill will be very common. Growth in 1968 will probably be only 10 percent of normal, with continuation of the reduced growth the following 2 years.

The moderately defoliated area covers about 20,000 acres (fig. 1). Jack pine stands within this area were brown after defoliation, but green foliage also was abundant. The defoliation in this area was very variable. Not only were there small pockets of severe and light defoliation mixed together but even tree-to-tree defoliation was variable. In general, growth loss over 50 percent of increment can be expected on the remaining 20,000 acres in which jack pine is abundant; the defoliation was light (fig. 1). Some browning was observed that indicated the presence of budworm. The actual growth loss from budworm feeding should not be great.

CHEQUAMEGON NATIONAL FOREST **North**
WISCONSIN



SCALE
0 1 2 3 4 5 6 Miles

LEGEND

National Forest Boundary

Jack pine type
Light Defoliation

Moderate Defoliation

Severe Defoliation

1967

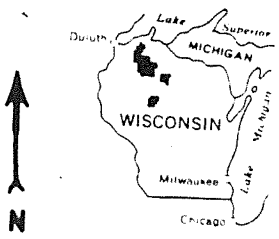


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Figure 1. Jack-pine bud-defoliation on the Chequamegon N. F.

Chippewa National Forest

The jack-pine budworm defoliation severity declined from 1966. Only one major area was classed as moderately defoliated. None of the defoliation was severe or to such an extent where tree mortality might be expected next year.

About 20,000 acres (gross area) received moderate defoliation (fig. 2). This area was north of the Cutfoot Sioux Ranger Station, surrounding and including the Avenue of Pines and the Experimental Forest. The older red pine had severe defoliation in the upper crowns and some top kill can be expected. Jack pine growth next year should be less than 50 percent of normal because of reduced foliage.

The remaining area, about 60,000 acres, received light defoliation (fig. 2). In general, defoliation was barely noticeable and little impact can be expected on the jack pine.

A tree mortality survey was conducted in the area where severe defoliation was observed in 1966 (fig. 3). This area apparently had had some budworm present for the past several years; however, extensive defoliation was not reported until 1966.

Five areas were surveyed for loss of merchantable volume of jack pine. Four of these areas were 30- to 40-year-old plantations grouped close together. The other area, block V, is situated by itself. The average volume loss was 24 percent, with a range from 10-36 percent (table 2). Only the trees completely dead were counted. Additional mortality is expected when severely top-killed trees succumb. The mortality among smaller trees, suppressed and intermediate, was more extensive but most of these trees were under merchantable size and therefore not counted.

Table 2.--Jack pine mortality on Chippewa National Forest in 1967 after 1966 defoliation by jack-pine budworm

Location				Merchantable volume		
Sample block:	T	R	S	Live: cords/acre	Dead: cords/acre	Percent mortality
I	145	29	10	4.70	0.51	10
II	145	29	9&10	8.80	3.10	36
III	145	29	10&11	10.43	2.28	18
IV	145	29	10&15	9.77	3.17	24
V	145	29	18	21.08	9.12	33

In addition, considerable top kill of plantation red pine was observed near Lydick Lake. Here, the red pine tops were above the jack pine canopy, but yet, many of them had the upper two or three whorls killed. The trees will recover, but the resulting crooks will probably remain for many years.

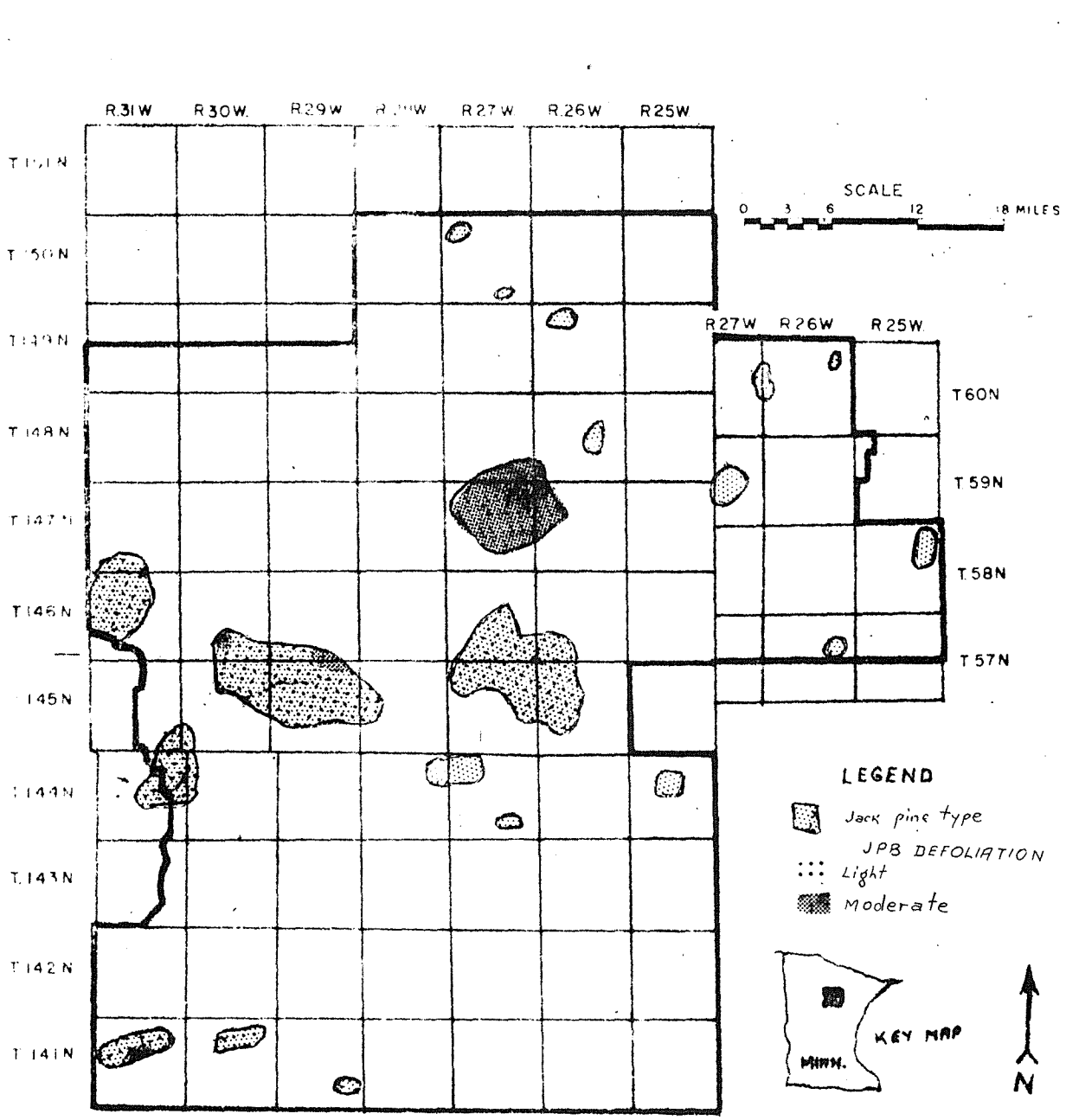


Figure 2. Jack-pine budworm defoliation on the Chippewa N. F. - 1967

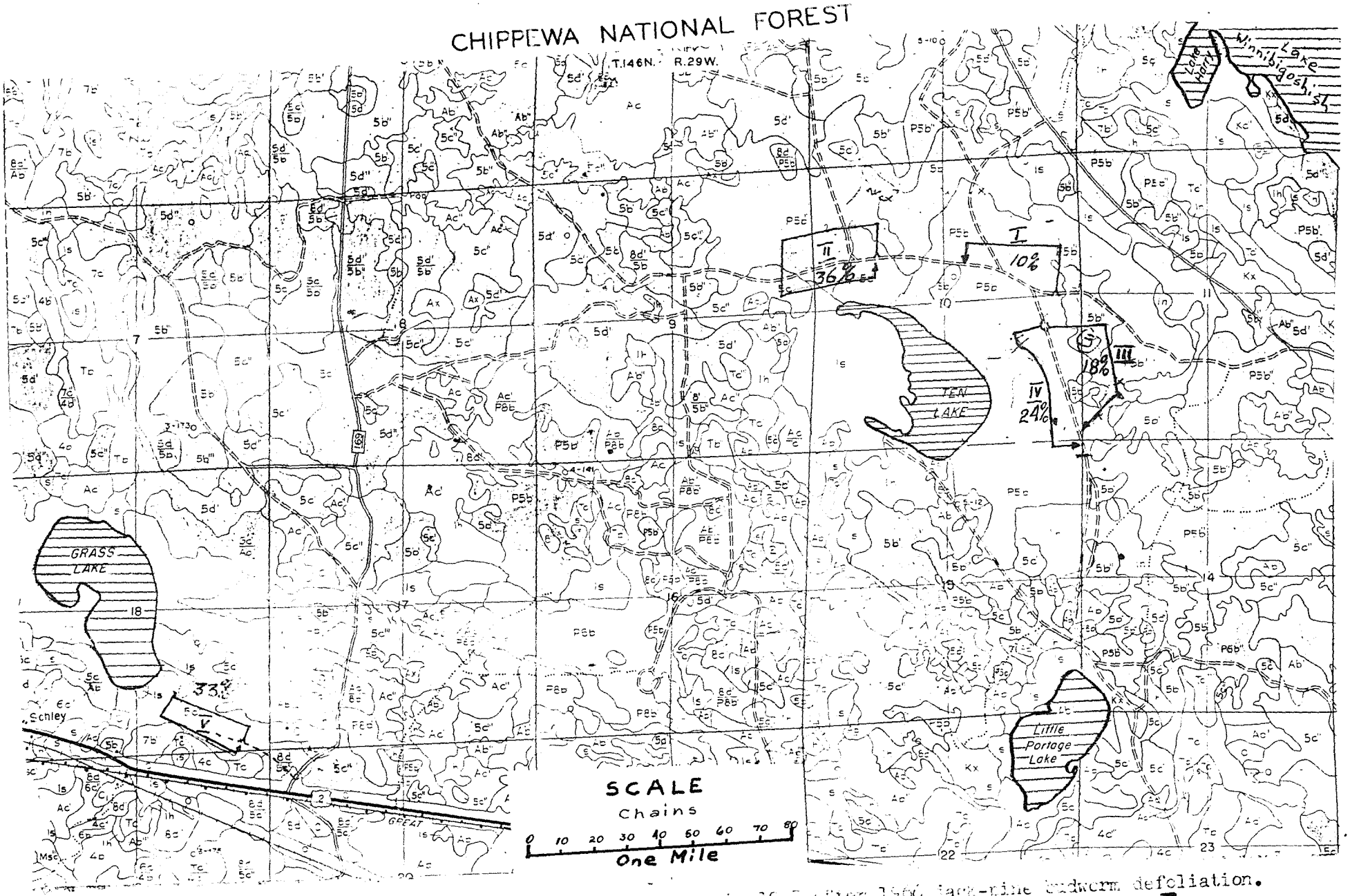


Figure 3. Jack pine mortality on the [illegible] in 1957 after 1956 jack-pine budworm defoliation. [I→ lines of survey. % percent of [illegible] volume dead. JP= jack pine type]

Hiawatha National Forest

Jack-pine budworm defoliation on the Hiawatha National Forest increased in area and intensity from 1966. Since the Forest is divided into two units, each one will be discussed separately.

East Unit

Severe defoliation was observed from the air on about 2,400 acres (fig. 4). The two northernmost centers are primarily young red pine plantations with widely scattered trees less than 25 feet tall. Some naturally seeded jack pine are scattered throughout. The red pine is severely defoliated in the upper crowns, while the jack pine is only moderately to lightly defoliated. This type of damage is not common, but has been reported by Kulman and Hodson (1961) in Minnesota. According to that report red pine top kill can be expected when the tops are more than 80 percent defoliated.

The southwest pocket of severe defoliation is centered primarily in Scotch pine. Some tree mortality can be expected. The southeast pocket is older jack pine. The defoliation was severe, but most of the loss can be expected from top kill and growth loss.

Moderate defoliation was mapped over a gross area of about 20,000 acres. Here the defoliation was obvious, but seldom were the trees completely stripped. Growth loss of over 50 percent will be the predominant effect.

Most of the remaining area, about 70,000 gross acres, had some budworm present, but defoliation was light. A small area south of Brevoort Lake had an endemic budworm population.

West Unit

Most of the budworm defoliation on the National Forest was centered around Steuben. From the air the browning was very evident; however, ground checks indicated sufficient presence of green needles for the trees to survive.

Severe defoliation was mapped (fig. 4) for two small areas, about 600 acres altogether. The northernmost severe defoliation pocket has primarily red pine, 10-20 feet tall. The situation appears similar to that described for the East Unit. However, the eastern severely defoliated pocket is older jack pine. Here the defoliation is severe, but green needles are present to permit the trees to recover. Growth loss in excess of 80 percent can be expected on the defoliated trees.

HIAWATHA NATIONAL FOREST
MICHIGAN
MICHIGAN MERIDAN

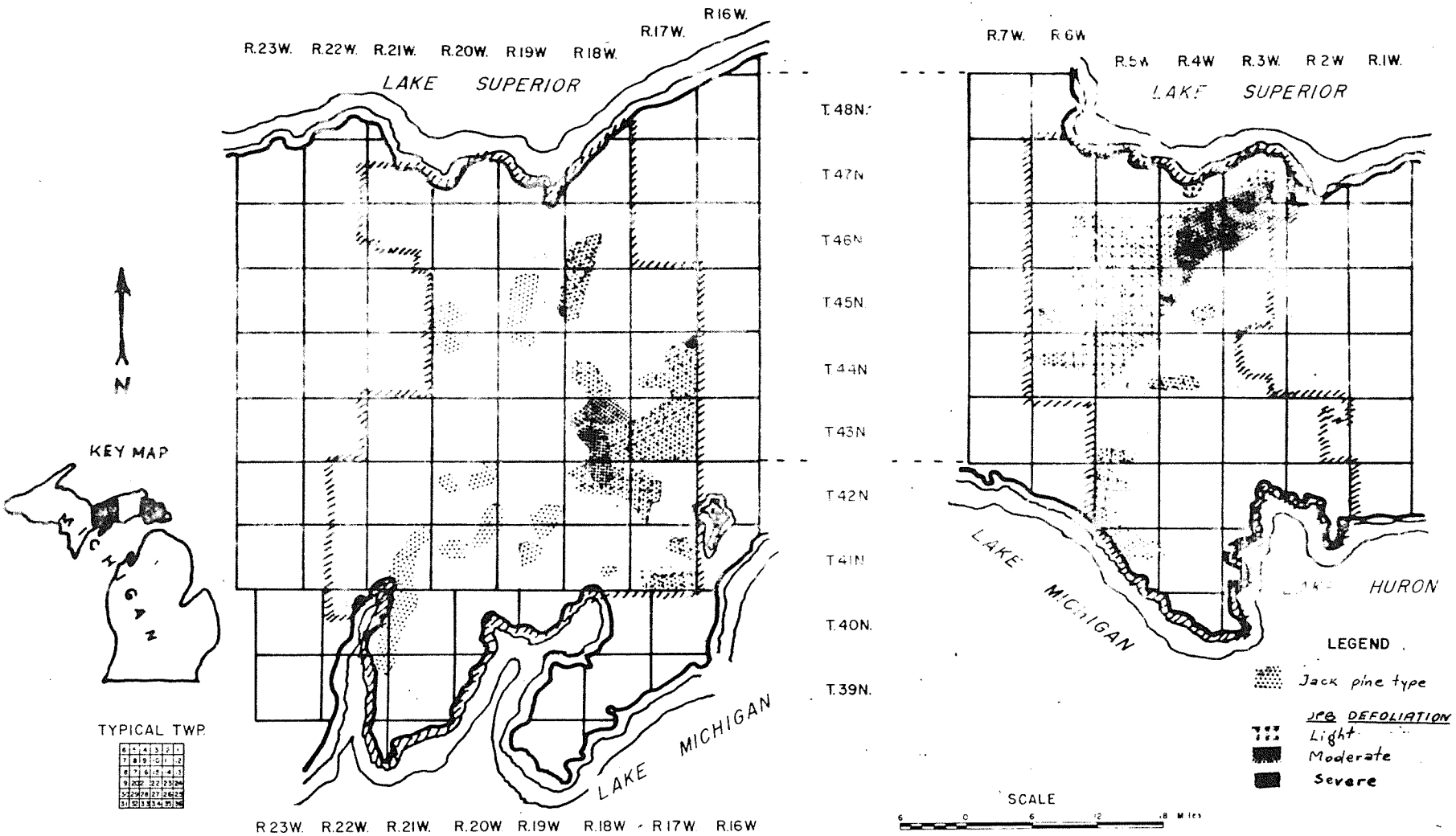


Figure 4. Jack-pine budworm defoliation on the Hiawatha N. F. - 1967

Moderate defoliation covers about 15,000 gross acres in the Steuben area. The severity of defoliation was very variable from one tree to another. Growth loss of about 50 percent may be expected. A few jack pines may end up top killed.

About 60,000 gross acres received light budworm defoliation. An additional 50,000-acre area of jack pine type had no visible budworm defoliation, but a few budworms were found during the egg mass surveys.

Huron National Forest

Jack-pine budworm defoliation in 1967 was the least since the 1963 eruption (Millers 1963, 1964, 1965, 1966). Barely noticeable defoliation was observed on the west end of the Mio Ranger District. Elsewhere defoliation was not visible from the air. Time did not permit ground checking, so further information is lacking.

Scattered tree mortality from previous years was observed in most of the older pine stands, usually on state or private property.

Manistee National Forest

Heavy rains and wind preceding the aerial survey knocked down most of the dead needles. Consequently, only severe defoliation was visible from the air. However, ground checking indicated light to moderate defoliation on jack pine from the Baldwin Ranger District north. Nowhere did defoliation exceed 50 percent.

Nicolet National Forest

No budworm defoliation was observed from the air on the National Forest. However, severe defoliation and tree mortality occurred on state and private land a few miles west of the Forest boundary near Conover, Wis.

Ottawa National Forest

Serious jack pine defoliation was observed only in the Baraga Plains area, northeast edge of the Forest (fig. 5). About 5,000 acres of jack pine were severely defoliated. Ground examination has not been made, but reports indicate that tree mortality can be expected next year. This area will be examined after dead needles and old needles have fallen in order to determine the need for salvage.

OTTAWA NATIONAL FOREST NE

MICHIGAN

MICHIGAN MERIDIAN

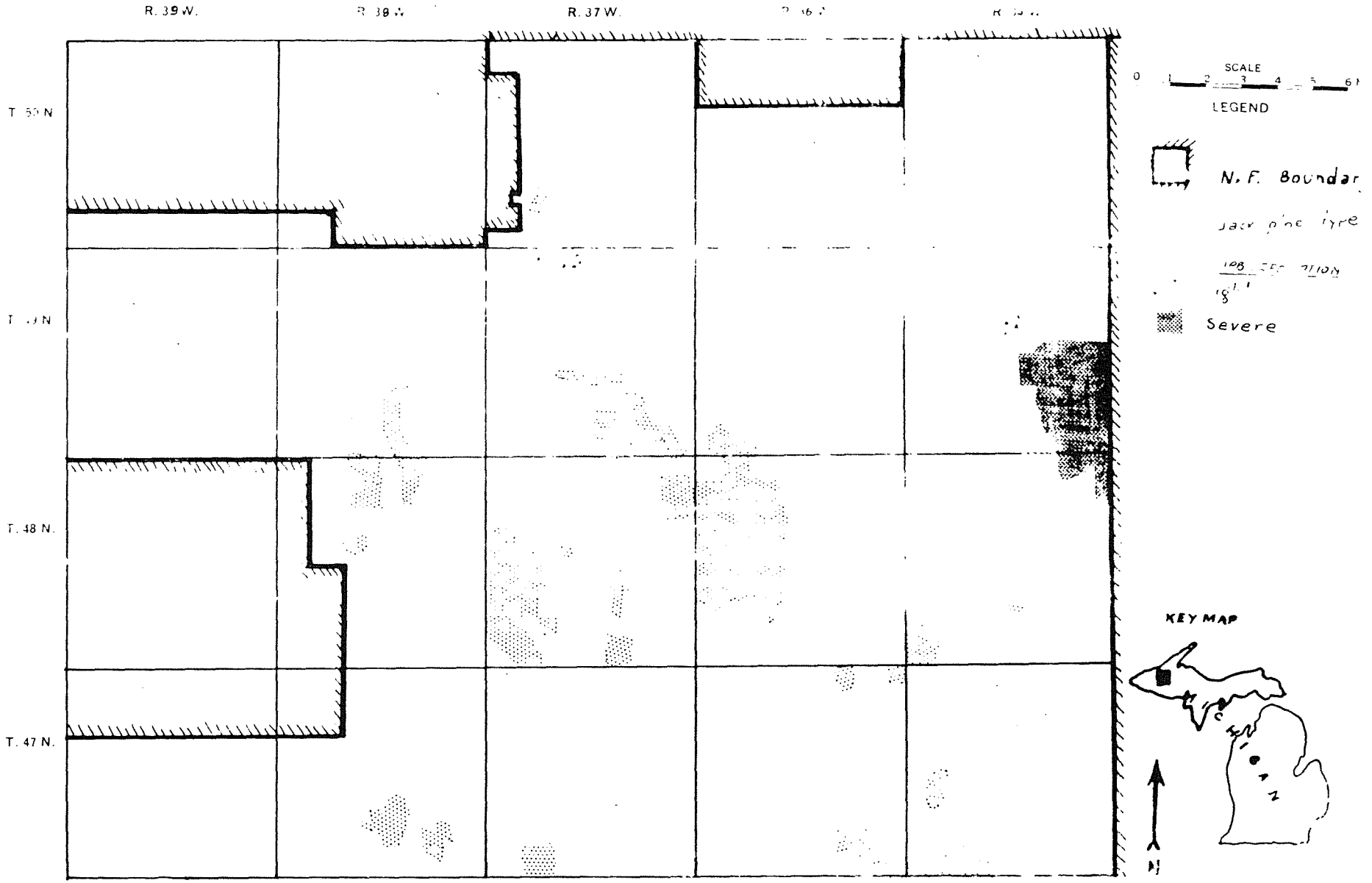


Figure 5. Jack-pine budworm defoliation on the Ottawa N. F. - 1967

The jack-pine budworm is present in other areas in very low numbers and did not cause economic losses.

Superior National Forest

Jack pine budworm defoliation was not observed during the aerial surveys. However, ground examinations indicated that budworm feeding was common (Appendix 1). Current defoliation should not cause significant growth loss.

G. Trend of Outbreak

The aerial survey determined the location and extent of current jack pine defoliation. The present budworm population that will contribute toward next year's defoliation was determined by a population trend survey.

Population Trend Survey

The main objective of making population trend surveys is to determine budworm populations annually so that eruptions can be foreseen before they reach damaging proportions. In addition, the same information can be used to determine need for suppression. Three or more permanent plots were placed in each major jack pine area. The plot establishment and collection procedures were developed by the research staff from the University of Michigan (Foltz 1967). Each plot consisted of a cluster of 10 dominant and codominant jack pine located in a typical pine stand representative of the area. Samples were collected by cutting two 36-inch-long branches from midcrown and similar branches from lower on the crown of each tree. The number of budworms and new shoots over 1 inch long were determined. The final calculations were expressed as number of budworms per 100 tips or shoots.

The initial plan was to time the survey when moths had just emerged. The pupal skins were to be used as an index showing the budworm population that caused the defoliation as well as estimating the number of females that were produced and available to lay eggs. Timing of the survey was critical, since a major rainstorm can knock most of the pupal skins out of the tree. Only the Huron-Manistee National Forests were successful in this survey.

Most of the other National Forests were sampled for egg masses. The general assumptions were as follows:

1. The average egg mass contains about 100 eggs.

2. Partially parasitized egg-masses will contribute toward the next years budworm population and therefore, are included in the total.(Appendix 1)

3. Egg-masses with more than 80% eggs parasitized will not contribute significantly toward next population and therefore are not included in total counts.

4. Populations with less than 1 egg-mass per 100 tips are not likely to produce more than light defoliation.

5. Populations with 1-4 egg-masses per 100 tips can produce moderate defoliation.

6. More than 4 egg masses per 100 tips can produce severe defoliation and more than 7 may give complete stripping of the pine.

Chequamegon National Forest

The expected jack-pine budworm population on the Washburn Ranger District is extremely high. The average sound egg-mass populations are 16 e.m. per 100 tips with a range from 11 to 31. The average for partially parasitized egg-masses is about 5 , with a range 2-10 (Appendix 1.) Thus, about 22 egg-masses per 100 tips will contribute toward next springs larval population.

The more northern block of jack pine is supporting more than double the jack-pine budworm population than is found in the southern area (Fig. 6.) The egg mass counts were high also in areas that had been very lightly defoliated in 1967. Thus, one might assume that the northern budworm population is on the increase, while the more southern area might have the same population as in 1966.

On basis of the assumptions given above,the only logical conclusion can be that the jack-pine budworm defoliation in 1968 will be extremely severe unless unusual population reductions occur. Since the total egg parasitizm is low (Appendix 1), it appears that the natural enemies will not be able to bring about sufficient population reduction to prevent severe defoliation. This means that chemical suppression should be planned if the economic values justify the costs. The whole jack pine area can be treated as a unit in survey and suppression plans.

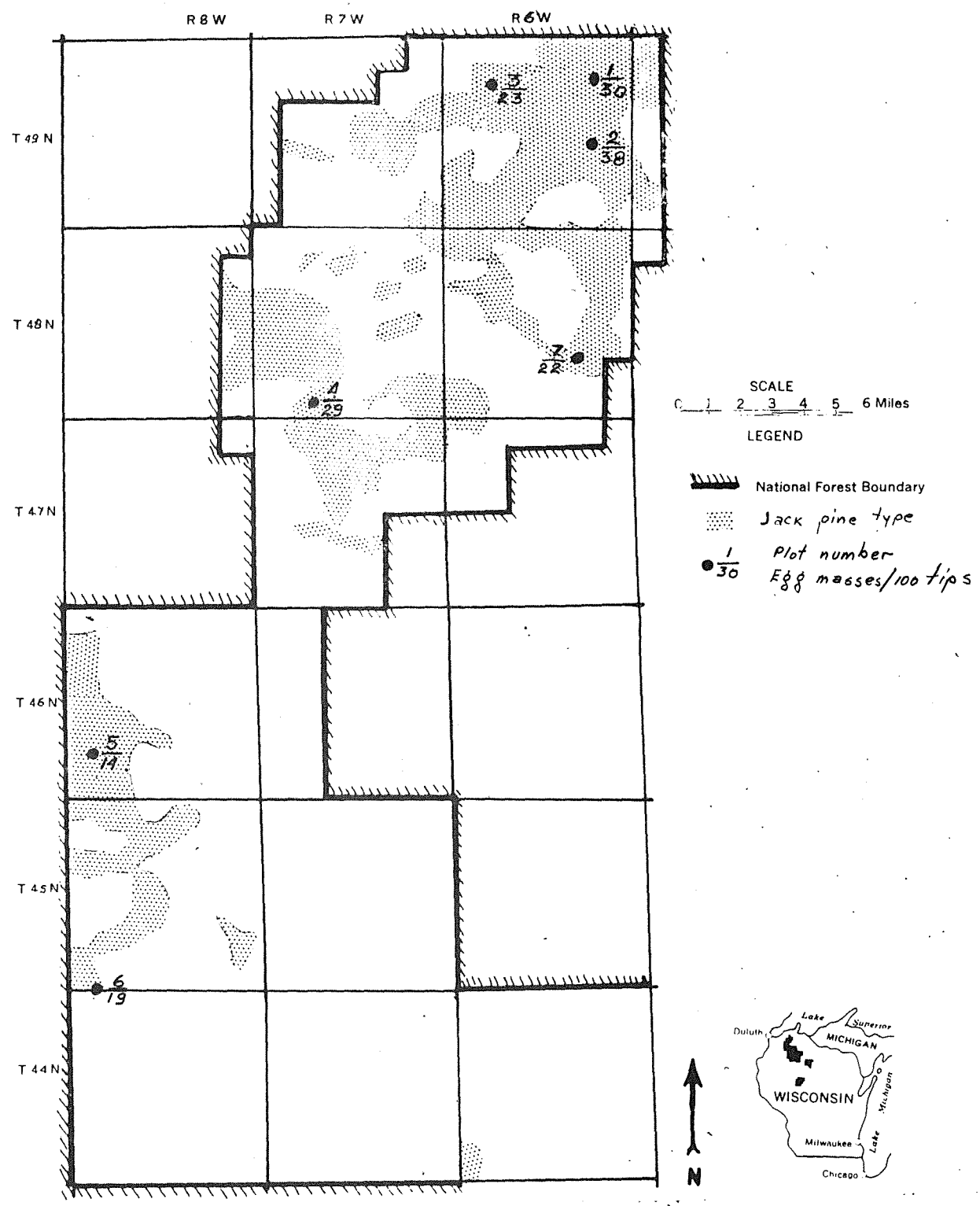


Figure 6. Jack-pine budworm egg-mass survey on the Chequamegon N.F.-1967

Chippewa National Forest

Low egg mass populations were recorded in most sample plots, except for the Avenue of Pines area (fig. 7 and Appendix 1). Overall, the egg parasitism was high indicating effective natural control. In most of the areas budworm populations should decline further in 1968. The exception might be the Avenue of Pines area.

The trend of budworm population at the Avenue of Pines is difficult to predict. While the egg masses are abundant, it is expected that this population should follow a downward trend as was observed in nearby areas. However, this is only speculative. On the basis of egg mass information alone, the prediction is that the Avenue of Pines budworm population may cause severe defoliation.

Hiawatha National Forest

East Unit

High egg mass counts in all the plots except plot 6, south of Brevoort Lake, were recorded (fig. 8 and Appendix 1). Egg parasitism appears low, suggesting that natural control factors will not be effective in 1968. Most of the area has an ample supply of foliage for production of staminate flowers and early budworm development next year. Foliage reduction on jack pine was observed south of township line 46N from causes other than jack-pine budworm. The addition of budworm defoliation in 1968 may cause severe effects on the jack pine.

The severity of red pine defoliation in 1967 suggests that in areas where red and jack pine are mixed or adjoining each other, the red pine damage should also be considered for 1968. Therefore, on the basis of the forementioned information, the biological prediction is that severe budworm damage will occur in 1968 unless chemical suppression is applied.

West Unit

High egg mass populations were found on the Manistique and Munising Ranger District plots, while the Rapid River plots had moderate populations (fig. 8 and Appendix 1). Egg parasitism was light, indicating that natural control factors are not effective at this time. The characteristics of 1967 defoliation indicate that an ample staminate flower and foliage supply will be available for early budworm development in 1968. On the basis of current information, moderate to severe defoliation can be expected in 1968 unless chemical suppression is applied.

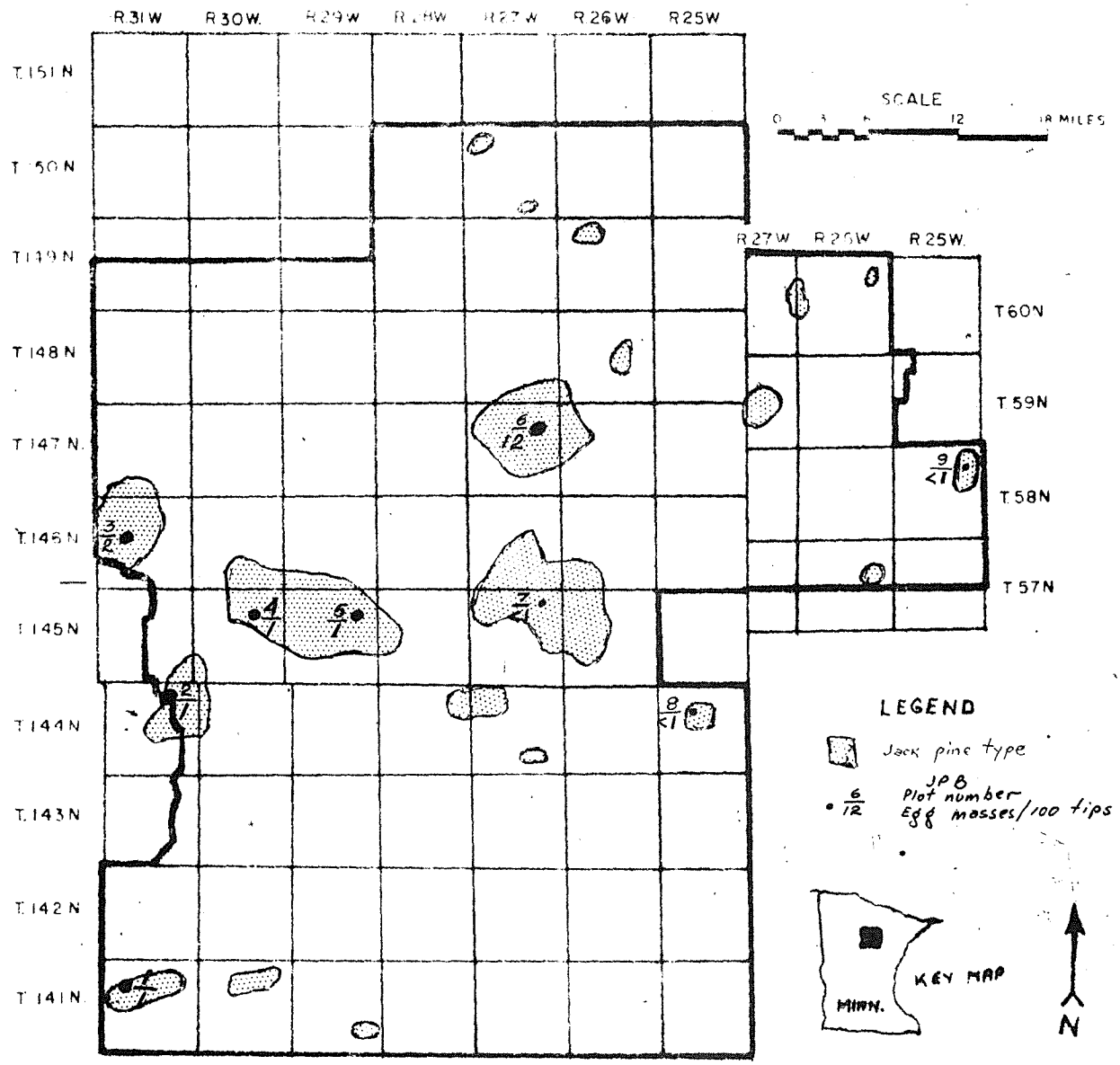


Figure 7. Jack-pine budworm egg-mass survey on the Chippewa N.F.- 1967

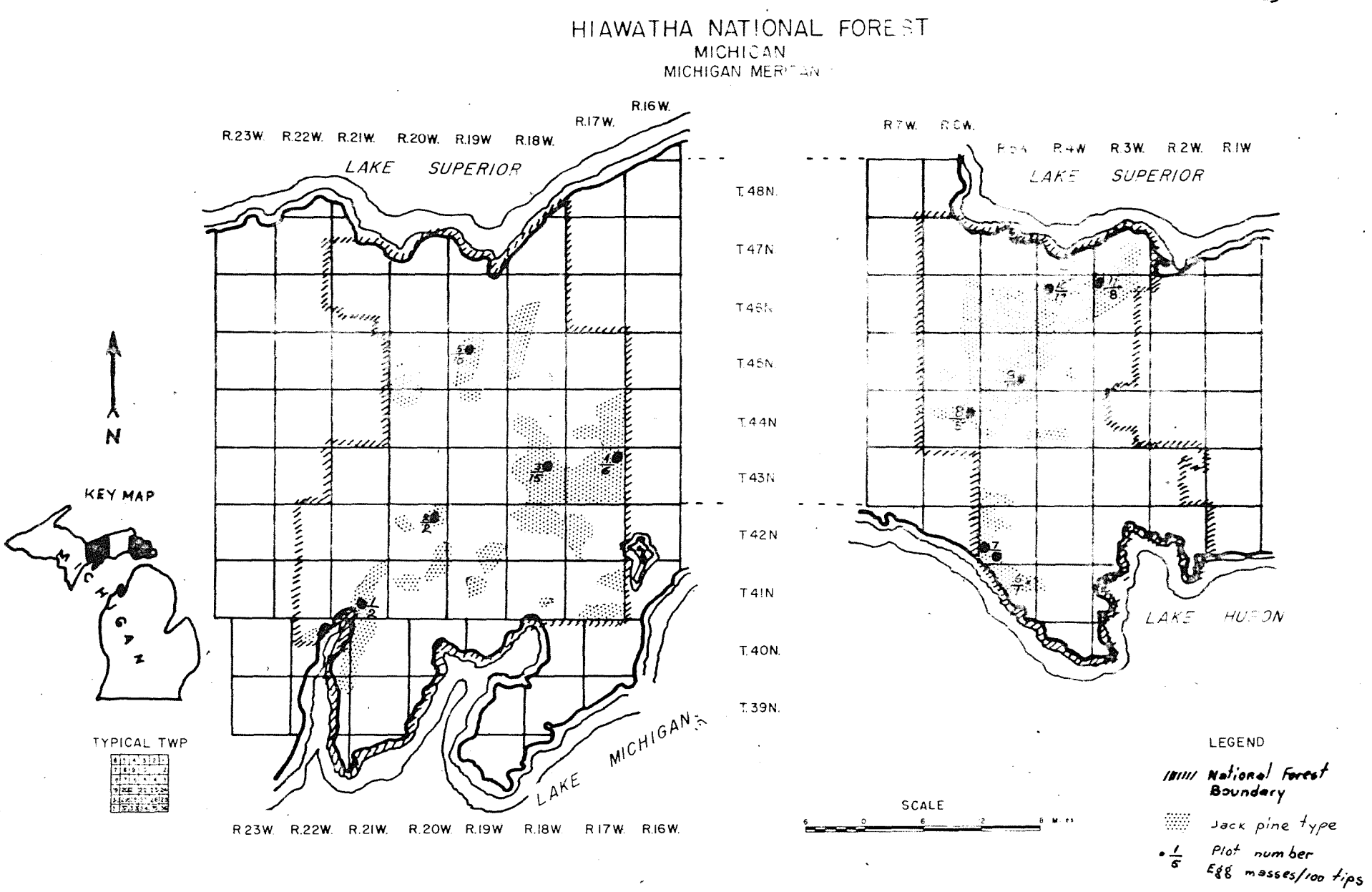


Figure 8. Jack-pine budworm egg-mass survey on the Hiawatha N.F.- 1967

Huron-Manistee National Forests

The new system of measuring population trends from pupal skins and live pupae needs additional evaluation. At present, the prediction for next year can be based on the assumption that half of the emerging moths will lay eggs at the rate of one egg mass each.

On the Manistee National Forest the emerging moth population was light with the exception of plot 8 (fig. 9 and Appendix 2). Larval and pupal mortality was relatively high, indicating that natural control factors are becoming effective. Light to moderate defoliation can be expected in some of the areas.

A moderate moth population was recorded on the west side of the Mio Ranger District, but elsewhere populations were low (fig. 10 and Appendix 2). Moderate defoliation may occur on the west side.

Nicolet National Forest

The egg mass survey indicates that the budworm populations are low in all major jack pine areas, except for the block west of Lac Vieux Desert campground, in the northwest corner of the Forest (fig. 11 and Appendix 1). Only one plot was taken in that area representing about 1,500 acres of jack pine. This area is close to the Conover infestation where severe defoliation during the past 2 years has resulted in heavy pine mortality. Therefore, severe defoliation can be expected unless chemical suppression is employed.

Ottawa National Forest

Low egg mass populations were found in most of the sample plots (fig. 12 and 13 and Appendix 1). The Baraga Plains area was sampled by Dr. Kinght's students, University of Michigan. Their four plots were within a few miles of plot 4 and therefore are applicable (Appendix 1). The Baraga Plains area could be severely defoliated again, although similarly defoliated areas in the past have experienced budworm population collapse.

On the basis of available information, the prediction is that further defoliation may occur on about 8,000 acres in the Baraga Plains area unless chemical suppression is employed.

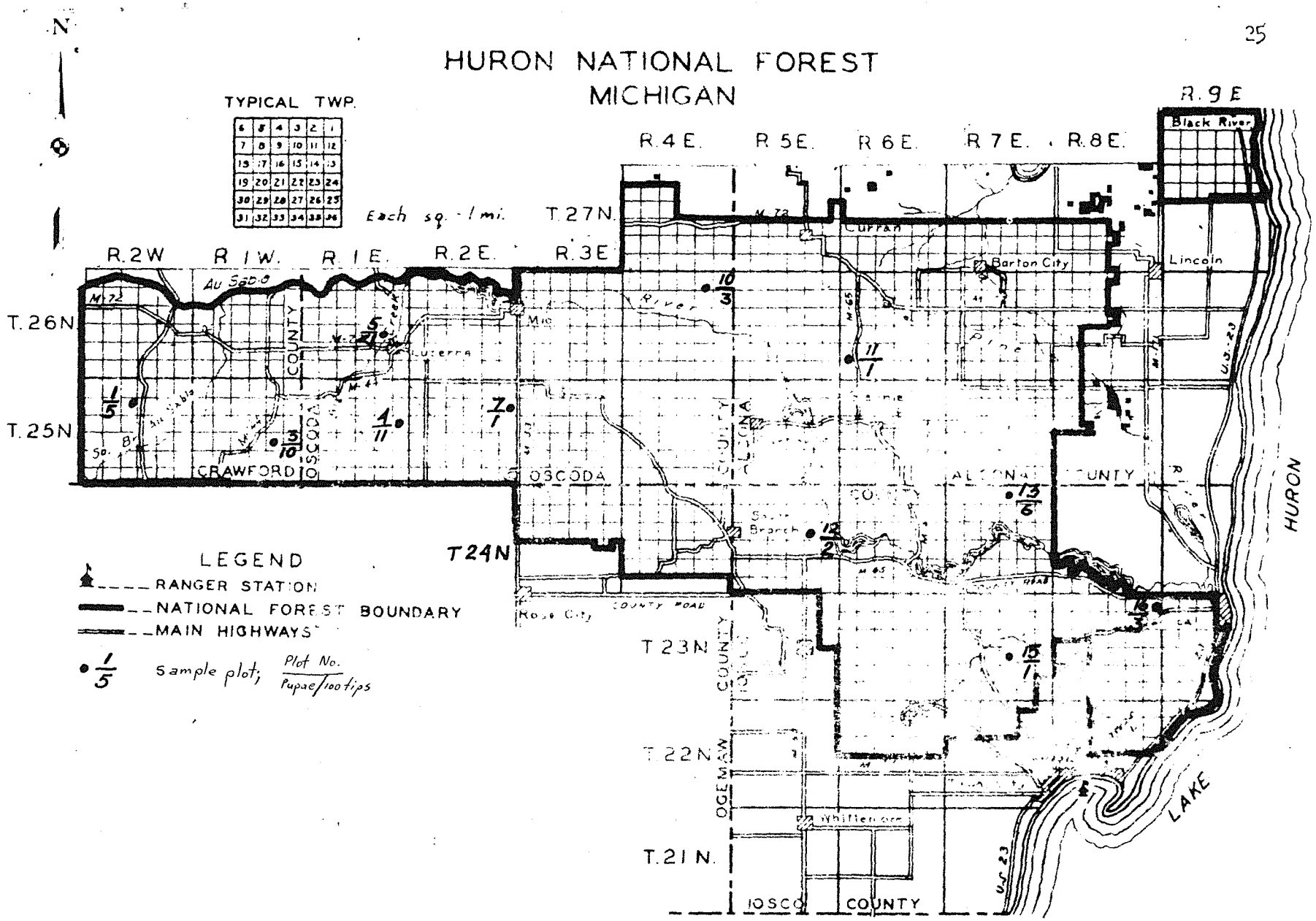


Figure 9. Jack-pine budworm pupal survey - 1967

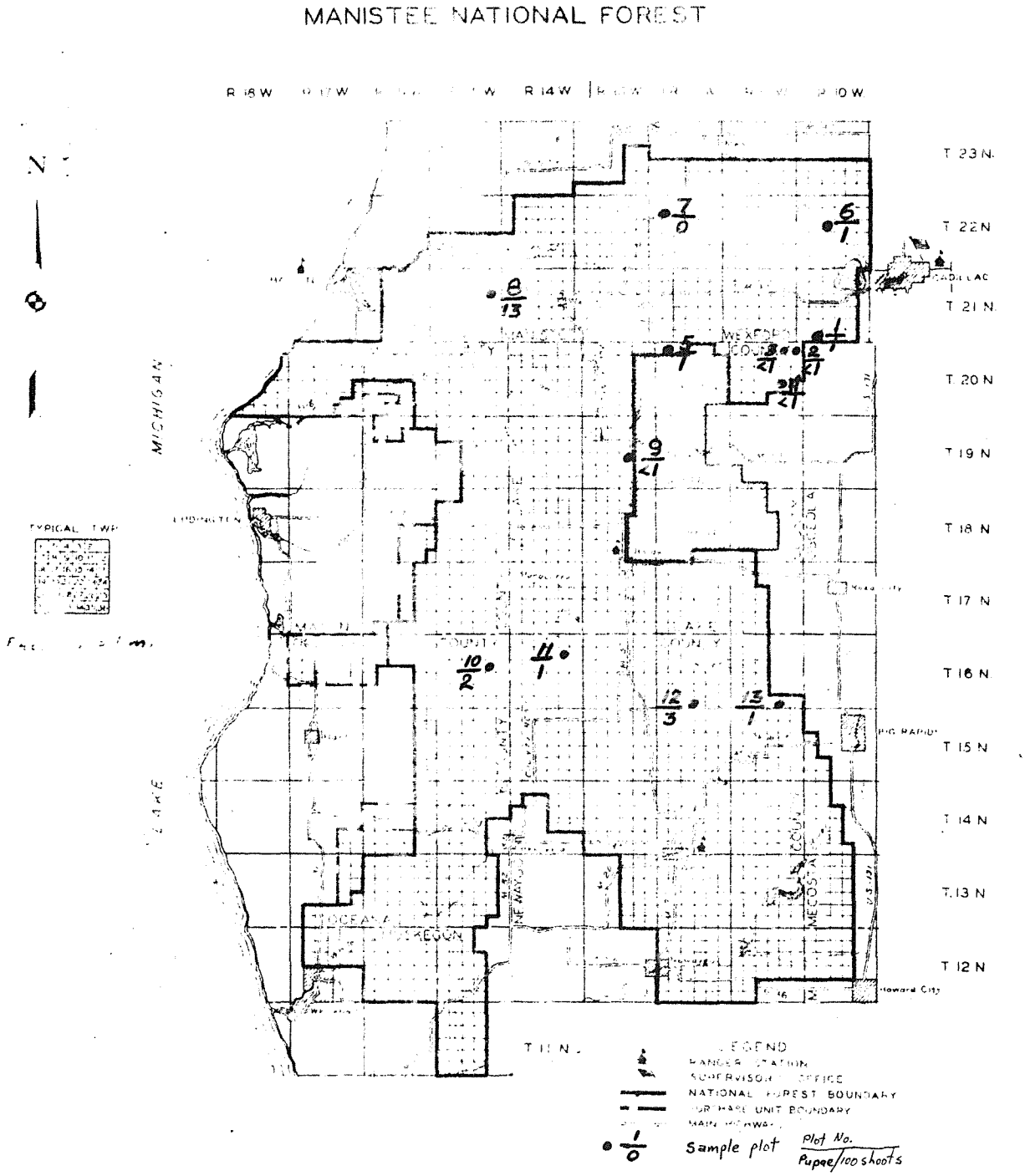


Figure 10. Jack-pine budworm pupal survey- 1967

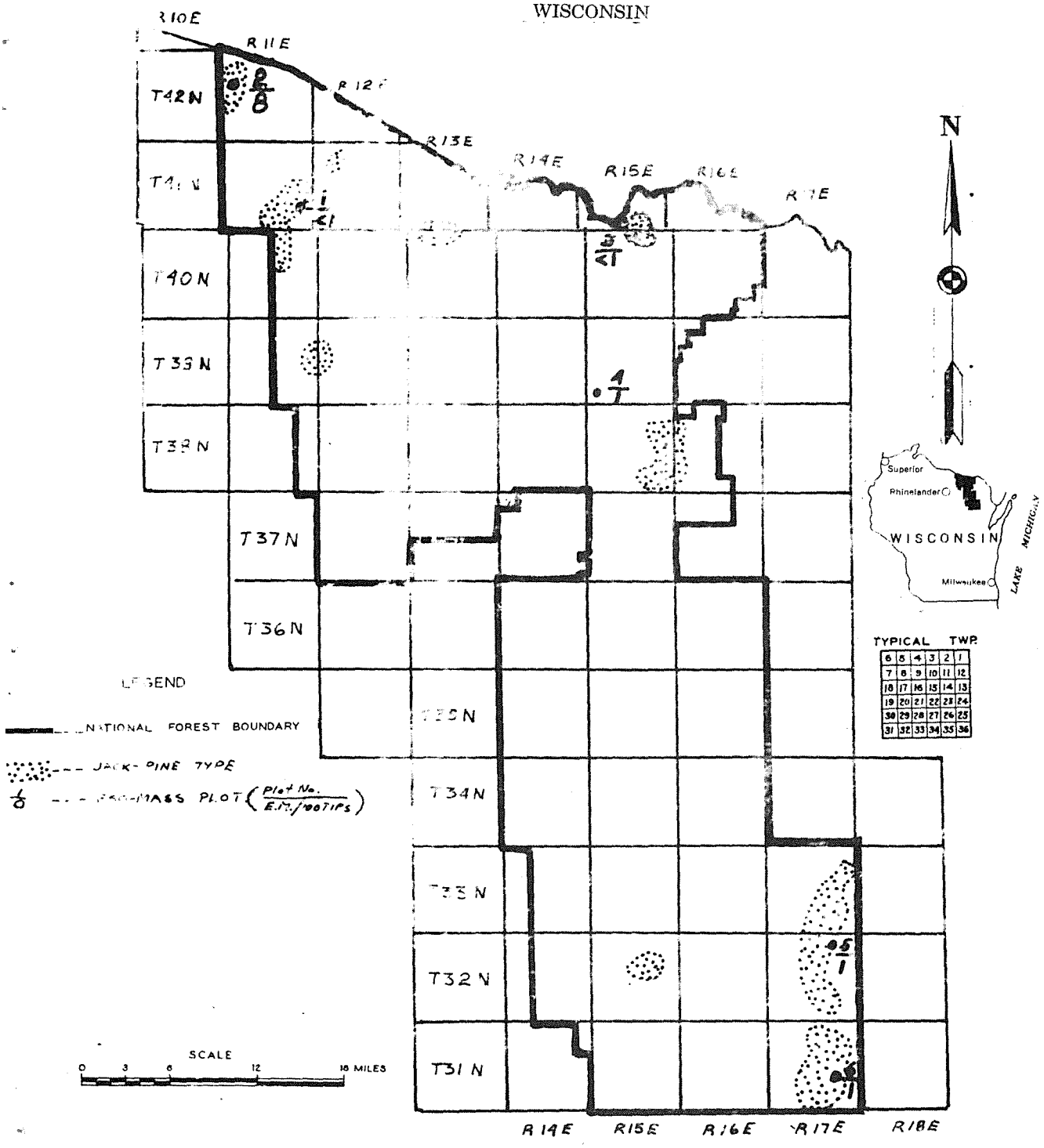
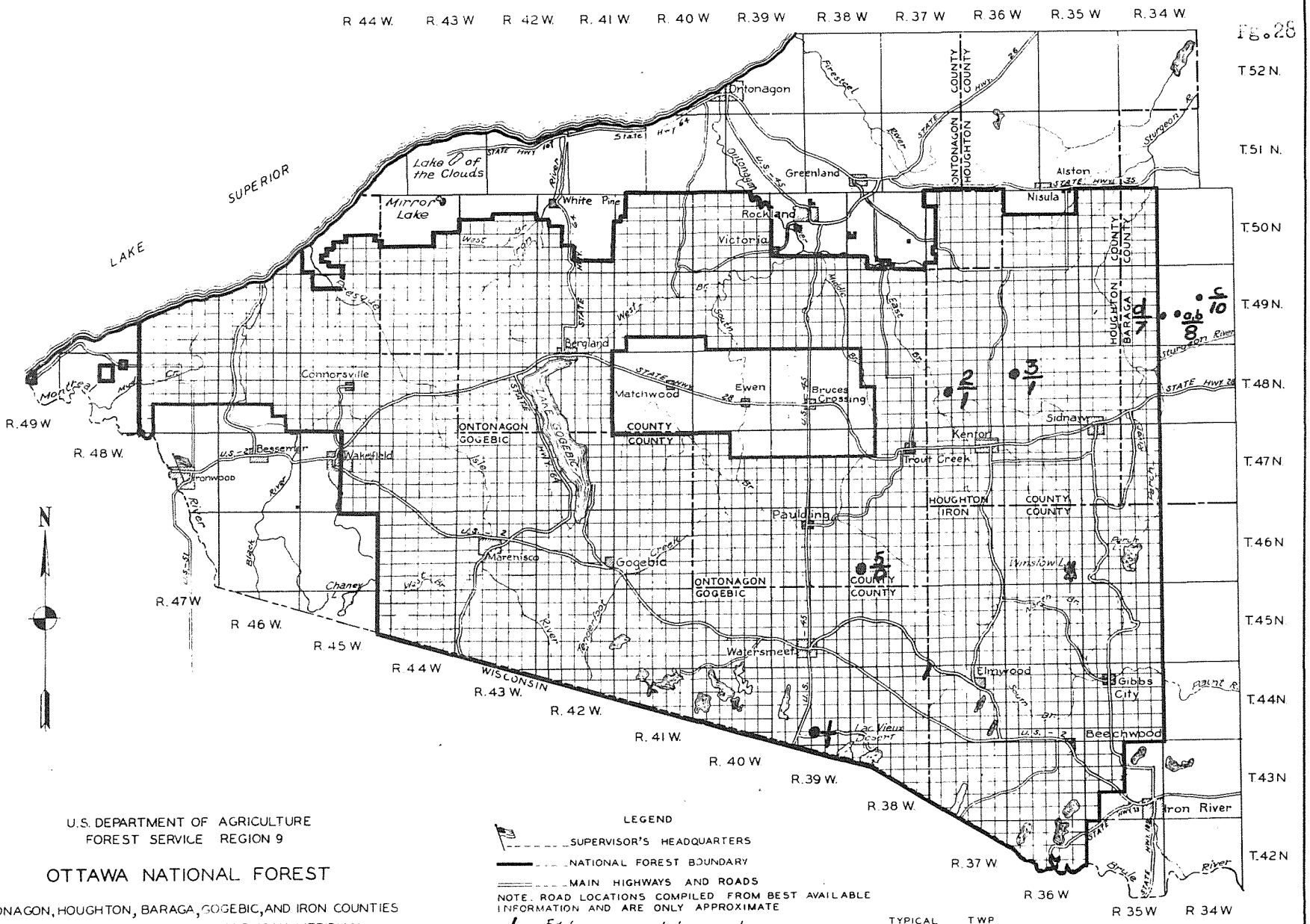


Figure 11. Jack-pine budworm egg-mass survey - 1967.



U.S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE REGION 9

OTTAWA NATIONAL FOREST

ONTONAGON, HOUGHTON, BARAGA, GOGEBIC, AND IRON COUNTIES
STATE OF MICHIGAN MICHIGAN MERIDIAN
1961

SCALE
0 3 6 12 18 MILES

LEGEND

SUPERVISOR'S HEADQUARTERS
NATIONAL FOREST BOUNDARY
MAIN HIGHWAYS AND ROADS

NOTE. ROAD LOCATIONS COMPILED FROM BEST AVAILABLE INFORMATION AND ARE ONLY APPROXIMATE

• 1/10 Egg-mass plot number
No. egg-masses/100 tips
a-c U. of Mich. plots

TYPICAL TWP

6	5	4	3	2	1
7	8	9	10	11	12
18	17	16	15	14	13
19	20	21	22	23	24
30	29	28	27	26	25
31	32	33	34	35	36

FOR INFORMATION CONTACT:
FOREST SUPERVISOR
U.S. FOREST SERVICE
IRONWOOD, MICHIGAN

Figure 12. Egg-mass survey - 1967

USDA-SCS-MILWAUKEE, WIS 1962

Superior National Forest

The egg mass surveys indicate light to moderate budworm populations (fig. 14 and Appendix 1). The nature of current defoliation indicates that these may be endemic populations that cause little damage. However, significant environmental changes could result in a rapid population increase. This has occurred in the past as recently as late 1950's. The abundance of old jack pine over 50 years old could result in abundant tree mortality if severe defoliation occurs.

Annual surveys should predict the population buildup and provide warning before tree mortality occurs.

H. Chemical Suppression

The jack-pine budworm has a long history of sporadic outbreaks throughout the Lake States. Frequently, chemical suppression has been required to prevent tree mortality. DDT has been the most effective insecticide, and the only one proven under operational conditions. However, Malathion and Zectran have been effective in pilot tests and can be considered for field use.

DDT

The insecticide most commonly used for jack-pine budworm control since 1945 is DDT; 1 pound technical DDT in 1 gallon No. 2 fuel oil, applied as 1 gallon solution from the air. This is also the only published recommendation (MacAloney and Drooz 1956).

The most recent report on a large jack-pine budworm control project is from Wisconsin (Benjamin et al. 1962). Over 32,000 acres were sprayed with an average budworm mortality of 78 percent ± 13.6, and a range of 47-91 percent. The postspray determinations were made just 72 hours after spraying. Additional mortality was expected and defoliation was effectively prevented.

Similar control was reported from Michigan (Batzer and Millers 1965). In small 20-acre replicated plots with light to moderate budworm populations, the average mortality due to DDT was 73 percent.

Tests conducted in Manitoba, Canada, have shown that DDT is effective at dosages lower than 1 pound per acre (De Boo 1967). The data have not been fully analyzed, but the rough estimates are as follows:

DDT/gal./acre	Acres treated	Percent control
3/4 lbs.	50	99
1/2 "	1,400	87
1/4 "	80	74

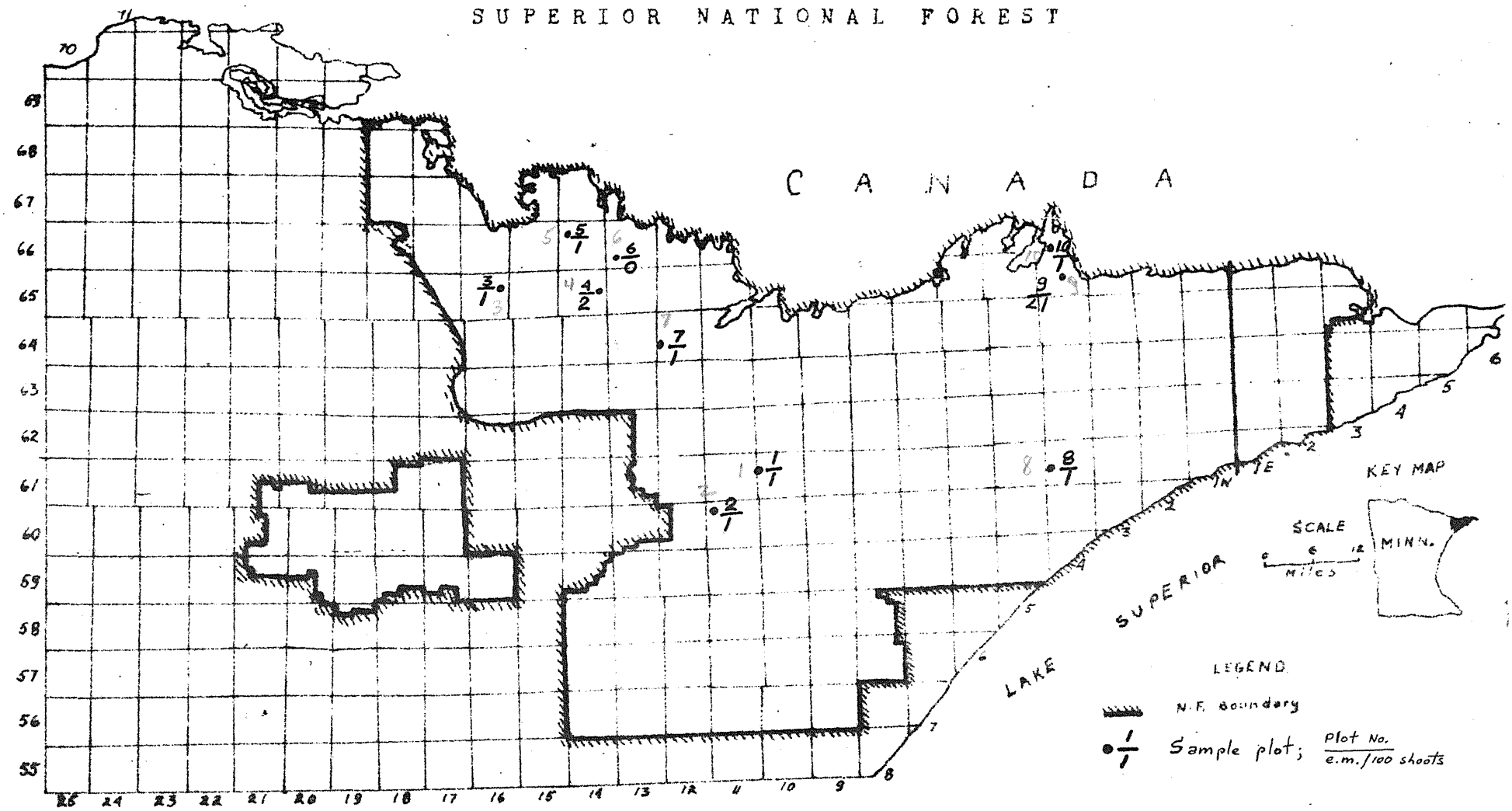


Figure 13. Jack-pine budworm egg-mass survey - 1967

All applications were made with fixed-wing aircraft. From this report it appears that the DDT dosage can be reduced to 1/2-1b. per gallon.

The variation in control effectiveness frequently is related to the type of budworm development. When most of the larvae are at the same developmental stage, effective control can be expected. During a cool spring, great variation in larval development occurs and control effectiveness is reduced.

Malathion

Malathion was first used against the jack-pine budworm in 1964 (Batzer and Millers 1965). One pound technical malathion was applied with Panasol as a 1-gallon solution per acre. The effective control in the pilot test was 66 percent.

Low-volume malathion concentrate was tested in 1966 (Millers and Batzer 1967). Malathion LV [R] was applied at the rate of 13 fl. oz. per acre (16 oz. tech. malathion). The average corrected control was 76.5 percent with a range of 52-95 percent.

In Wisconsin, 8 fl. oz. of malathion LV [R] concentrate gave only 46-percent control (Renlund 1967). Similar tests, but with 16 fl. oz. of malathion concentrate gave approximate control of 64 percent in 1967 tests (Renlund 1967).

The above summary indicates that malathion gives mediocre control. The major problem appears to be that the total volume of liquid may not be sufficient to provide insecticide coverage on all foliage. However, the control appears sufficient to protect trees from severe defoliation for a season. An operational large-scale test is needed to evaluate this insecticide more fully. It may be suggested that an 18 fl. oz. rate per acre applied by fixed-wing aircraft be tested operationally. This dosage rate and application method should give acceptable control.

Zectran

Zectran [R] is a relatively new insecticide that has been used against the spruce and jack-pine budworms.

Limited tests in Michigan indicated that Zectran is equal to DDT in effectiveness when it is applied as 1 lb. per gallon of water per acre (Batzer and Millers 1965). The average mortality was 85 percent with a range from 73-95 percent. Low-volume Zectran was applied successfully in Wisconsin in 1967 (personal communications with Wisconsin Conservation Department entomologists). Zectran was applied at the rate of 0.15 lb. per acre in 1 pint solution. Cursory examination of survey data indicates that near 90-percent mortality was achieved.

Considerable biological information is available on the side effects of Zectran from the Forest Service Pesticide Laboratory at Berkeley. All indications are that it is a reasonably safe material to wildlife.

However, at the present time, Zectran is not available for commercial operations. Indications are that it will not be available for other than testing purposes in the foreseeable future. On the basis of this, Zectran cannot be recommended for use in 1968.

Suppression Costs

Chemical

The cost of insecticides usually is reduced on large-volume operations and for governmental agencies. The cost of DDT is about ~~$.25~~ .50 per pound per gallon.

The cost of malathion LV[R] concentrate has been about $.65 per pound.

Aircraft

Application costs (i.e., money paid to the aerial applicator) vary with the size of the project and the gallonage to be applied. One gallon per acre application may cost about $1.00 per acre for a 10,000-acre project, while only $.70 for a 50,000-acre job. Low-volume malathion aerial application costs are lower and can be estimated at $.70 and $.40 respectively.

Cost of Manpower

The number of larval surveys and their intensity contribute the greatest labor cost. Additional expense is the ground marking and supervision of the operation. The cost per acre varies greatly with the acreage surveyed and eventually sprayed. Spring larval population surveys may appear as an unnecessary expense; however, local budworm population declines can be detected and the areas eliminated from the project. As a result, the per-acre cost increases, but the total project cost decreases.

Manpower costs for DDT application can be estimated at $1.50 per acre for 10,000-acre project and about $1.00 for a 50,000-acre job. Low-volume malathion can be applied at a faster rate and costs should be about $1.25 and $.80 respectively.

Total Cost

A 10,000-acre project cost can be estimated at $~~2.75~~ 3.00 per acre for DDT and $2.60 per acre for malathion LV.

A 50,000-acre project costs are estimated at $2.~~00~~ 25 per acre for DDT and $1.85 per acre for malathion LV.

I. Silvicultural Control

1. Maintain vigorous jack pine stands.

   Jack-pine budworm damage is more severe on stunted, weakened, slow-growing jack pine. While a vigorous tree may recover from budworm defoliation, similar foliage reduction can be fatal to a weak tree.

2. Harvest mature stands.

   A stand where the decadence is equal to increment might be considered at maturity and it should be harvested. Usually, it is determined from tree growth curves and then applied over a large area. For jack pine, maturity is considered around 55-60 years. However, trees growing on sandy, dry sites achieve maturity earlier than trees growing on good sites. Budworm outbreaks begin to appear when jack pine stands reach about 30 years. Thereafter, defoliation and growth reduction can be expected every 5-10 years unless chemically prevented. Therefore, early jack pine harvest should be considered in areas where recurring outbreaks are likely. The harvest may be timed immediately after severe defoliation. As a guideline, the cost of spraying should be less than the expected increase in timber value for the next 5 years. In many cases this means that spraying should be considered primarily as holding action to improve age balance and even annual cut.

   On moderate and poor sites, perhaps cutting should be planned at 40 years or shortly after budworm outbreaks.

3. Eliminate mixed plantations.

   The jack-pine budworm can cause top kill on red pine, thus reducing timber quality. Usually the damage occurs when red pine is mixed with jack or Scotch pines.

4. Maintain adequately stocked stands.

   Tree vigor is reduced when jack-pine stands are too dense; i.e., basal area over 140 square feet per acre. Too-open stands permit large tree crowns and increased staminate flower production, a favorable budworm environment.

J. Biological Recommendations

Jack-pine budworm outbreaks are reported from all three Lake States. Population declines are apparent on the Chippewa, Huron, and Manistee National Forests. No defoliation was reported from the Nicolet National Forest, but the population trend survey indicates a buildup in the northwest corner. Budworm populations were abundant on the Chequamegon, Hiawatha, and Ottawa National Forests. Severe defoliation is predicted for these areas in 1968. Specific biological recommendations are presented by Forests.

Chequamegon National Forest

1. Re-examine jack pine management guides to effect better silvicultural control of the jack-pine budworm.

2. Propose chemical suppression program for 1968 if resource values justify it. DDT at 1 lb. or 1/2 lb. per acre in 1 gallon fuel oil is recommended. Malathion LV ^{R} concentrate at 18 fl. oz. per acre may be considered as a substitute if lower effective control is acceptable. The whole jack pine area should be considered for suppression.

Chippewa National Forest

1. Re-examine jack pine management guides to incorporate silvicultural control practices for the jack-pine budworm.

2. The Avenue of Pines area may be considered for chemical suppression if special values need protection. However, there is a good possibility that the budworm population will decline. If severe defoliation occurs, perhaps the pine can be harvested.

Hiawatha National Forest

1. Re-examine timber management practices to effect better silvicultural control of the jack-pine budworm and to reduce losses.

2. Chemical suppression is recommended for the whole jack pine area in the East Unit; i.e., Soo and St. Ignace Ranger Districts. In the West Unit, chemical suppression is recommended for all currently defoliated jack pine stands; i.e., areas shown with defoliation in figure 2. The insecticide recommendation is the same as that for the Chequamegon National Forest.

Huron-Manistee National Forests

Re-examine timber management practices to incorporate silvicultural control suggestions for jack-pine budworm.

Nicolet National Forest

1. Re-examine timber management practices to incorporate silvicultural control suggestions for jack-pine budworm.

2. Follow the budworm population trend closely at Lac Vieux Desert area in order to prescribe an early timber sale, should severe defoliation occur in 1968.

Ottawa National Forest

1. Re-examine timber management guides to incorporate silvicultural control suggestions for jack-pine budworm.

2. Examine Baraga Plains jack pine for possible need of salvage cutting.

3. Re-evaluate suppression needs this fall after ground checks are made on defoliation. If chemical control appears necessary, the same insecticide recommendations as given for the Chequamegon National Forest should apply.

Superior National Forest

Re-examine timber management practices to incorporate silvicultural control recommendations. The jack-pine budworm population is relatively low, but old age stands can become serious problem areas should sudden budworm eruption occur.

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APPENDIX I - DATA FROM JACK-PINE BUDWORM POPULATION TREND SURVEY

BASED ON EGG-MASS COUNTS FROM LAKE STATES NATIONAL FORESTS IN 1967

LOCATION					STAND DATA				NO. OF EGG MASSES/100 TIPS			
National Forest	Plot	T	R	S	Basal Area sq.ft.	Age (Years	Site index (Ht 50 Yrs)	Defoli-ation	Sound	Partial Para-sitized	Total Para-sitized	Total Egg masses
Chippewa	1	141	31	8	70	27	50	*L	0.16	0.31	1.33	1.80
	2	144	31	3-10-11	100	24	60	None	0.28	0.28		0.56
	3	146	31	16	120	33	52	L	2.49			2.49
	4	145	30	10	120	45	54	None	0.65			0.65
	5	145	29	11	150	35	53	M	0.52	0.26		0.78
								Ave.	0.82	0.17	0.27	1.25
	6	147	27	14	110	35	55	M	10.57	1.05	0.12	11.74
	7	145	27	2	130	50	52	L	0.13		0.45	0.58
	8	144	25	8	130	30	75	L	0.18		1.10	1.28
								Ave.	3.63	0.35	0.56	4.53
	9	58	24	14	130	30	62	None	0.40			0.40
								Ave.	0.40			0.40
Superior	1	61	11	13	130	62	50	None	0.48	0.32		0.80
	2	60	11	7	120	60	52	None	1.40			1.40
								Ave.	0.94	0.16		1.10
	3	65	16	13	140	65	42	L	1.41			1.41
	4	65	14	24	150	62	45	L	1.95			1.95
	5	67	14	7	140	76	48	None	0.55			0.55
	6	66	13	20	120	60	44	L	.00			.00
	7	64	12	19	110	32	58	L	1.29			1.29
								Ave.	1.04			1.04
	8	61	4	19	120	47	54	None	1.40			1.40
	9	65	4	32	110	51	52	None	0.67			0.67
								Ave.	0.74			0.74

* L = Light; M = Moderate; S = Severe

APPENDIX I - DATA FROM JACK-PINE BUDWORM POPULATION TREND SURVEY

BASED ON EGG-MASS COUNTS FROM LAKE STATES NATIONAL FORESTS IN 1967

LOCATION					STAND DATA				NO. OF EGG MASSES/100 TIPS			
National Forests	Plot	T.	R.	S.	Basal Area (Sq.ft.)	Age (Years)	Site Index (Ht 50 yrs)	Defoliation	Sound	Partial Parasitized	Total Parasitized	Total Egg Masses
Chequamegon	1	49	6	11	90	30	50	M	20.91	9.24	0.32	30.47
	2	49	6	23	130	45	58	M	31.49	6.74		38.23
	3	49	6	8	100	32	52	M	20.95	2.29	0.10	23.34
	4	48	7	33	110	24	60	L	18.77	10.29	0.20	29.26
	7	48	6	23	140	25	72	L	15.96	6.56	0.18	22.70
								Ave.	20.62	7.02	0.20	28.20
	5	46	8	20	90	30	58	L	10.65	3.33	0.11	14.09
	6	45	8	31	170	32	58	L	12.33	6.73		19.06
								Ave.	11.49	3.35	0.06	16.57
Nicolet	1	41	11	26	140	35	62	None	0.31			0.31
	2	42	11	8	60	43	78	None	7.38	0.43		7.81
	3	41	15	4	90	33	48	None	0.09			0.09
	4	39	34	31	130	33	65	None	0.64			0.64
								Ave.	2.10	0.11		2.21
	5	32	17	2	120	38	60	None	0.80			0.80
	6	31	17	22	140	33	70	None	0.57			0.57
								Ave.	0.69			0.69
Ottawa	1	44	39	34	130	33	80	None	0.89	0.11		1.00
	5	46	38	30	60	34	67	None	.00			.00
								Ave.	0.45	0.06		0.50
	2	48	37	20	120	32	70	L	0.78	0.20		0.98

APPENDIX I - DATA FROM JACK-PINE BUDWORM POPULATION TREND SURVEY

BASED ON EGG-MASS COUNTS FROM LAKE STATES NATIONAL FORESTS IN 1967

LOCATION					STAND DATA				NO. OF EGG MASSES/100 TIPS		
National Forest	Plot	T.	R.	S.	Basal Area (Sq ft.)	Age (Years)	Site Index (Ht 50 Yrs.)	Defoliation	Sound	Partial Parasitized	Total Parasitized	Total Egg Masses
Ottawa	3	48	36	18	100	33	52	None	0.81			0.81
								Ave.	0.80	0.10		0.89
	Rob.N	49	34	19	83	40	55	M-S	6.64			6.64
	CFI 2021	49	34	15	70	35	54	S	10.24			10.24
	Rob.W	49	34	20	50	40	48	M	4.23			4.23
	Rob.E	49	34	20	40	40	48	M-S	11.48			11.48
								Ave.	8.15			8.15
Hiawatha	1	41	21	22	90	22	62	None	1.91	0.21		2.12
	2	42	20	11	110	29	58	None	1.87	0.85		2.72
								Ave.	1.89	0.53		2.42
	5	45	19	16	100	22	72	L	9.55	0.84		10.39
								Ave.	9.55	0.84		10.39
	3	43	18	15	120	44	55	L	14.60	0.18		14.78
	4	43	17	1	110	44	66	L	5.42	0.11		5.53
								Ave.	10.01	0.15		10.16
	8	44	6	14	120	37	58	L	4.88	0.45		5.33
	9	45	5	27	80	32	58	L	13.33	1.85	0.12	15.30
	10	46	4	8	70	35	54	L	15.12	1.67		16.79
	11	46	3	6	40	39	48	M	7.80	0.44		8.24
								Ave.	10.56	1.10	0.03	11.42
	6	41	5	14	90	22	72	None	0.10			0.10
	7	42	5	19	120	26	82	None	4.43	0.09		4.52
								Ave.	2.75	0.05		2.31

APPENDIX II - DATA FROM JACK-PINE BUDWORM POPULATION TREND SURVEY

BASED ON PUPAL COUNTS FROM HURON-MANISTEE NATIONAL FORESTS IN 1967

LOCATION					STAND DATA			NO. OF PUPAE/100 TIPS	
National Forest	Plot	T.	R.	S.	Basal Area (Sq. ft.)	Age (Years)	Site Index (Ht 50 Yrs.)	Defoliation in 1967	Pupal Skins & Live Pupae	Dead Pupae
Manistee	1	21	10	32	120		60	*L	.89	.30
	2	20	11	1	140		60	L	.32	.09
	3	20	11	2	120		50	L	.18	.13
	4	20	11	23	90		70	L	.22	.09
								Ave.	.38	.15
	5	20	12	5	100		50	M	1.26	.17
	6	22	10	16	160		80	L	.18	.00
	7	22	12	17	130		60	L	.00	.00
	8	21	15	13	110		50	M	13.40	5.40
	9	19	13	15	110		50	L	.11	.00
								Ave.	2.99	1.11
	10	16	15	14	130		70	L-M	2.26	.30
	11	16	14	11	90		70	M	.60	.03
	12	16	12	33	130		60	L	2.67	.86
	13	15	12	3	110		70	L	.75	.10
								Ave.	1.57	.32
Huron	1	25	2	9	90		50	L	5.45	.39
	3	25	1	23	130		50	L	9.58	.84
	4	25	1	13	110		50	L-M	11.41	2.04
	5	26	1	23	130		50	L	.37	.11
								Ave.	6.70	.85

Continued on next page

* L = Light; M = Moderate

APPENDIX II - DATA FROM JACK-PINE BUDWORM POPULATION TREND SURVEY

BASED ON PUPAL COUNTS FROM HURON-MANISTEE NATIONAL FORESTS IN 1967

LOCATION					STAND DATA			NO. OF PUPAE/100 TIPS		
National Forest	Plot	T.	R.	S.	Basal Area (Sq.Ft.)	Age (Years)	Site Index (Ht 50 Yrs.)	Defoliation in 1967	Pupal Skins & Live Pupae	Dead Pupae
Huron	7	25	2	12	140		50	L	.64	.13
	10	26	4	2	90		50	L	2.81	.29
	11	26	6	30	130		60	L	1.18	.22
									Ave. 1.89	.21
	12	24	5	14	60		50	L	2.00	.25
	13	24	7	3	90		50	L	4.58	1.62
	15	23	7	22	130		50	L	1.44	.58
	16	23	8	1	80		50	L	2.84	.26
									Ave. 2.72	.68

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JACK-PINE BUDWORM DEFOLIATION ON RED AND JACK PINES NEAR AVENUE OF PINES, CUT-FOOT - SIOUX R.D., CHIPPEWA N.F. - 1967

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